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ADVANCED INSTRUMENTATION AND AUTOMATION FOR FILLING AND PACKAGING OF BEVERAGES

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ABSTRACT

Increasing competitive pressures, more stringent legal regulations, rising costs of commodities and energy and consumers with rapidly changing preferences force the beverage companies to increase their flexibility and operate with maximum efficiency at the same time. The safer and easier path to optimization leads through integrated automation. Addressing the filling and packaging line of beverages with the aim of optimization and cost effective automation undoubtedly requires keen attention for the advanced instrumentation. For the competitive solutions, various sensors and control systems must be carefully selected and efficiently implemented.

This paper presents the overview of the filling and packaging line of the beverage industry. Important issues related to the automation of such lines are overviewed and the real time example of one such successful implementation is discussed. The system components are clearly defined and important considerations are discussed with reference to actual implementation of the system. Qualitative comparison of controller is presented to facilitate the selection process for cost effective optimization. Control valve operating mechanism, electric drives and significance of PLCs are also discussed. An innovative HMI approach implemented in a specific industry is discussed as a real time example. This paper is aimed to provide firsthand quality information to the beginners with reference to filling and packaging line in the beverage industries.

KEYWORDS: Filling, Packaging, Proximity Sensors, Automation, SIMATIC Controller, Drives

INTRODUCTION

In the present era of highly growing technology, automation has become so much mandatory in almost each and every field, especially in food and beverage industries for filling and packaging purpose. PLCs (Programmable Logic Controller) are most widely used for automation in many industries in order to increase productivity and to reduce cost. There are too many machines required in this line starting from unloading of used bottles to packaging and conveying of filled bottles. All these functions are carried out automatically in a logical sequential manner. All these machines have different functionalities for different applications. Different types of sensors are used for object detection, fault detection, safety purpose etc. Variable frequency drives are used for speed control of motors. Different types of control valves are also used for subsequent control actions. Based on the type of the containers used in specific application area, the corresponding filling and packaging lines constitute of different machines. The mainly used types of containers are PET (Poly Ethylene Terephthalate) bottles, RGB (Returnable Glass Bottles), and CAN. KHS Machinery Pvt. Ltd. offers customized solutions in filling and packaging technology for the beverage sector in India. Totally integrated automation covers the complete production line, from receipt of goods, the production process, filling and packaging, to shipment of

goods. Various processes involved in the filling and packaging lines are controlled using PLC. A PLC is a digital device used for automation of electrical as well as mechanical processes. The functionality of the PLC has developed over the years to include sequential relay logic, motion control, process control, distributed control systems and networking. PLCs are mainly designed for applications which require multiple inputs and outputs, better temperature ranges, protection to electrical noise, and resistance to vibration. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory [1, 2].

Generalized Layout of Filling and Packaging Line

Figure 1 shows generalized layout of filling and packaging line for CSD(Carbonated Soft Drink) with RGB as a container. In case of beer filling with RGB as a container, there is one more machine required after filler; called pasteurizer for pasteurization of beer.

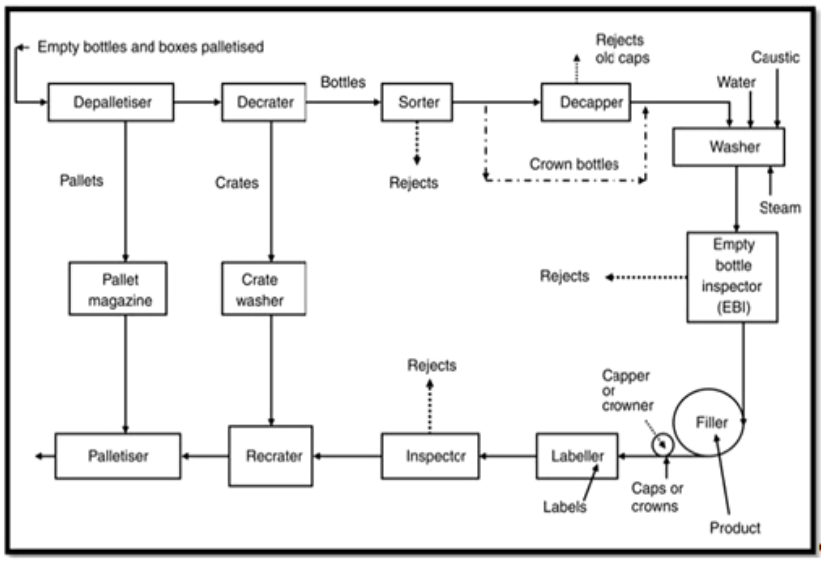

Figure 1: Generalized Layout of Plant

In a typical glass bottle filling line, the first operation is to unload the empty used bottles from the crates onto a conveyor. A depalletizer is the machine used to remove each layer of crates from the pallet and send them to the decrater for unloading of the bottles from the crate to the bottle conveyors. From the decrater, bottles are fed to a bottle washer, which fully washes the returnable glass bottles to reduce microbiological contamination of the product to be packaged into the container, ensuring that no extraneous objects such as pieces of glass, etc. are present, and removing any old labels, ink jet coding and small particulates such as sand and dust. After this washing process it is necessary to inspect bottles for soiling, broken necks, leftover liquid and foreign objects usually down to some 2.5 mm which is the optical limit of most bottle inspectors. It is also possible to remove scuffed bottles. After that, bottles are fed to filler and after filling, bottles are directed towards labeller. After labelling, bottles are again checked for liquid level, proper label position etc. Then bottles are fed to the crater for packaging and finally to the palletizer[3, 4].

ADVANCED INSTRUMENTATION

Sensors, control valves, motors and drives-all these terms are related to instrumentation of most of the machines. Sensors are invariably necessary in any industry for tasks like fault detection, object detection, safety etc. Depending on the applications, different types of sensors are used. Table 1 enlists important information related to the sensors used for

filling and packaging machines especially developed by KHS Machinery Pvt. Ltd.

Different control valves are used to control various process parameters such pressure, temperature, flow and liquid level by fully or partially opening or closing in response to signals received from controllers. The controllers compare a "set-point" with a "process variable", whose value is provided by sensors, which monitor changes in such conditions [5]. Filling the beverages into containers is the most important and critical process because during this process level, pressure, temperature and flow - all these parameters of beverage should be maintained at some fixed point so opening and closing of valves play most important role [6]. These valves can be operated using three different mechanisms:

- Mechanical
- Electro - pneumatic and
- Electronic

In a mechanically operated valve all movements are controlled mechanically. Component parts of the filling valve which are inside the filler bowl (the product valve and gas needle) are operated by a control lever which, in turn, is raised and lowered by cams external to the ring bowl. Pressurisation and filling phases are controlled by this operation.

The electro-pneumatic type consists of mechanical filling valves with electro - pneumatic control. This type of filling valve has a product valve and gas needle controlled by a pneumatic cylinder on top of the filler bowl. All operations are electronically controlled, eliminating the control cams outside the filler bowl. As fillingphases arecontrolled electronically, optimum filling is possible at varying speeds. In the electronic type, a level probe is integrated into the vent tube. This allows the level control to be operated from the level probe. This type of valve is particularly suitable when bottles with different fill points are being filled as the fill level can be adjusted electronically [3].

DC and/or AC motors are most widely used in food and beverage industries in conveyor application to transfer materials, bottles, crates or boxes from one position/ location to another. DC and/or AC variable frequency drives are used to control the motor speed and torque by varying motor input frequency and input voltage.

Table 1: Typical Sensors Used in Filling and Packaging Machines

	Type	Purpose	Applications	Manufacturer
IF 5811 IF 5545 IG 5319 IM 5115	Inductive proximity sensor	Detection of metallic objects	**Filler**: Crown detection **Conveyor**: Bottle flow detection **Bottle washer**: Gear box safety **Caser**: cycle sensor	IFM Electronics, Germany
LSSR 46B.8 - S12 (Through beam type) PRK 46B/44.01- S12 (Reflective type)	Photoelectric Sensor	Use light sensitive elements to detect the object	**Caser**: Safety sensor **Filler**: Bottle gap detection **Bottle washer**: In-feed and discharge safety	Leuze Electronics, Germany

Table 1: Contd.,				
PSEN SL - 1.0P - 1.1	Magnetic proximity sensor	Detects the presence of permanent magnets	**Filler**: Door interlock	Pilz Gmbh, Germany
UB4000 - 30GM - E5 - V15	Ultrasonic proximity sensor	Detection of any objects	**Caser**: Caser infeed conveyor speed control	Pepperl + Fuchs Gmbh, Germany
Liquicap M FMI51	Capacitive level sensor	Measurement of liquid level	**Filler**: To measure liquid level in bowl	Endress + Hauser, Switzerland

Today, AC drives are widely used in all kinds of processes. Variety of applications of AC drives range from the raw material handling to pumping and mixing of ingredients; from processing to conveyor and fan control; as well as during packing and storage. The advantages of AC drives are considerable improvements in plant efficiency, energy savings and reduced wear on moving equipment.

All AC drives convert AC to DC, and then through various switching techniques invert the DC into a variable voltage, variable frequency output.

In typical DC drive, the SCR converts the fixed voltage alternating current(AC) of the power source to an adjustable voltage controlled direct current (DC) output, which is applied to the armature of a DC motor.

Danfoss VFD (Variable Frequency Drive) drives are most commonly used in every machines of KHS Machinery Pvt. Ltd. for speed control. These drives can be of two types:

- Central drives and
- Decentral drives

Whether to use central or decentral drives depends on the layout of the bottling plant, the distance from the control room to theconveyor motors and the installation cost for electrical cabinets and cables[7].

Figure 2 shows centralized installation of drive, in which motor controls means drives are placed in a central place so there is a need for power cables from the centrally placed drives to the motors.

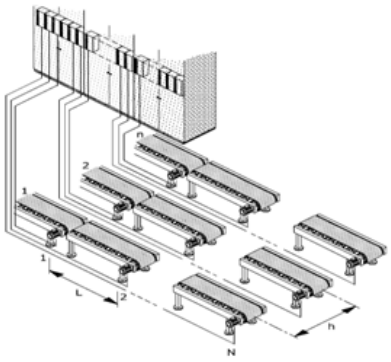

Figure 2: Centralized Installation

As shown in Figure 3, Decentral drives are meant forde-located mounting, where the need for space consuming control cabinets is eliminated. With the drives placed near or directly on the motor, thereis no need for long screened motorcables [8].

AUTOMATION

The field of automation has a notable impact in a wide range of industries beyond manufacturing. Automation is nothing but the utilization of control systems and information technologies to minimize the need for human work in the production of goods and services.

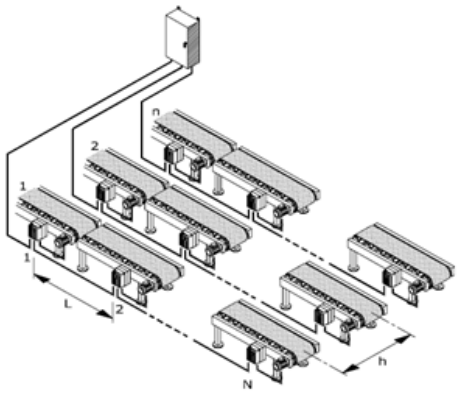

Figure 3: Decentralized Installation

In the scope of industrialization, automation is a step ahead of mechanization. Mechanization generally refers to human operators with machinery to assist them with the muscular requirements to work, where as automation greatly decreases the need for human sensory and mental requirements as well.

Traditional approach of bottle filling and packaging involves placing bottles onto a conveyor and filling only one bottle at a time and further moving it for packaging. This approach is very time consuming and expensive. So, automation in this area proves to be very much useful as it reduces the cost, saves time and also improves quality and productivity.

Programmable Logic Controller (PLC) is one of the most widely used control equipment for automation in various industries. Leading manufacturers of PLCs in today's market are Allen Bradley, B&R, Delta, Siemens, Mitsubishi, Motorola, Omron etc. The Siemens PLC called SIMATIC S7-300 universal controller is specially designed for innovative system solutions in manufacturing, distinctively the automotive and packaging industries.This modular controller serves as an ideal universal automation system for centralized and decentralized configurations [9].

The S7-Controller consists of a power supply (PS), a central processing unit (CPU) and signal modules for in and/or output devices (I/O devices). If necessary, communication processors (CPs) and function modules (FMs) can also be used for specific tasks (e.g. stepping motor control)[10].

STEP 7 is the standard software package used for configuring and programmingSIMATIC programmable logic controller. With STEP 7, one cancreate S7 programs in below mentioned standard languages [11]:

- Ladder Logic(LAD)
- Statement List (STL)
- Function Block Diagram (FBD)

The programmable logic controller supervises and controls a machine or a process in concurrence with an S7 program as shown in Figure 4. The I/O devices are addressed in the S7-Program via the Input (I) and Output addresses (Q) [10].

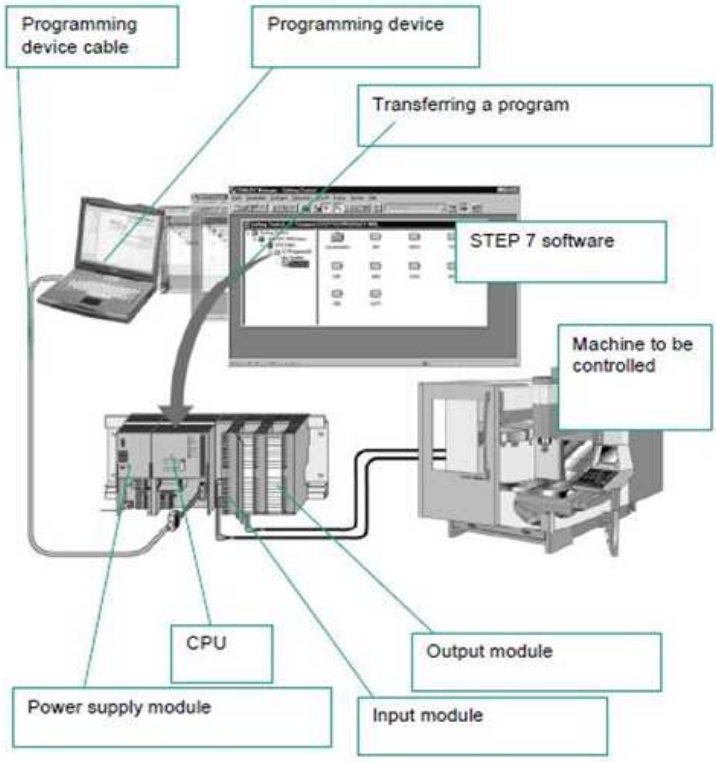

Figure 4: Automation of a Machine

Table-2 shows the comparison between different CPU modules which are available for S7 - 300 series. Depending on requirement and application, CPU module can be chosen [12]. CPU 317 - 2 PN / DP is in use for most of the application nowadays as it has some advanced features compare to others like:

- Increased RAM
- Lesser command runtime
- More number of timers and counters
- Large number of analog and digital channel I/Os
- It supports both Ethernet and Profibus communication interfaces

Signal modules are the interface of the SIMATIC S7-300 to the process.A host of different digital and analog modules provide exactly the inputs/outputs required for each task.Digital and analog modules differ with reference to the number of channels, voltage and current ranges, electrical isolation, diagnostics and alarm functions, etc.

Table 2: Comparison of Different CPU Modules

	CPU312	CPU314	CPU315-2DP CPU 315-2 PN/DP	CPU 317-2 DP CPU 317-2 PN/DP
RAM	32 kB	96 kB	128 /256 kB	512 /1024 kB
Instructions	10 k	32 k	42k /84k	170k /340k
LoadMemory	MMC (Max 4 MB)	MMC (Max 8 MB)	MMC (Max 8 MB)	MMC (Max 8 MB)
CommandRuntime	Min 0.2 us	Min 0.1 us	Min 0.1 us	Min 0.05 us
FB / FC	512	2048	2048	2048
DataBlocks	511	511	1023	2047
Timers /Counters	128 /128	256 /256	256 /256	512 /512
AddressSpace I/O	1k /1k	1k /1k	2k / 2k	8k / 8k
No. of Digital Channel I/O	256 / 256	1024 /1024	16384 /16384	65536 /65536
No. of Analog Channel I/O	64 /64	256 /256	1024 /1024	4096 /4096
Operable FMs	8	8	8	8
Operable CPs (LAN)	4	10	10	10
Communication Interfaces	X1: MPI	X1: MPI	X1: MPI X2: DP X2: PN	X1: MPI /DP X2: DP X2: PN

Function modules are intelligent modules that independently execute the technological tasks like counting, measuring, cam control, PID control and motion control. Thus they reduce the load on the CPU. They are used when a high level of accuracy and dynamic response is required.

Communication processors are used for connecting S7-300 to the different bus systems / communication networks as well as for point-to-point link. According to application case and module different protocols and different bus systems are available like PROFIBUS, DP or Industrial Ethernet [9].

HMI (Human Machine Interface) is also a good concept in the field of automation. An HMI is a software application that presents information to the operator or user about the state of a process, and to accept and implement the operators control instructions. Typically, criticalinformation is displayed in the graphic format.

At KHS innovative ClearLine HMI operator panel meets all the requirements of modern and complex machine operation and provides easy gaining and role-based access to all KHS machines. RFID access control enables the machine operator to easily log in at a machine simply by holding his/her ID card in front of the RFID antenna. This system automatically identifies the user, the user's role (e.g. machine operator, maintenance staff, and administrator) and displays the data and menus relevant for the particular user[13].

An outstanding key advantage of the HMI is that the different graphical user interfaces of individual machines have been combined to form a uniform system for entire production line.

Major features of these innovative Clear Line HMI concepts are [14]:

- Smooth and efficient production operation
- Uniform operation of all machines throughout the plant
- Simple and intuitive

- Role-based authorization concept and minimized loss through operator access control
- Safe tracking of user activities using Audit Trail
- Automatic storage and file management for log files
- Energy-saving hardware concept

In short, this Clear Line HMI concept simply simplified something complicated.

CONCLUSIONS

Overview of the sensors used in different machines of filling and packaging line of beverages is presented. In the field between the opposing poles of complex processes and cost-effective operation, the SIMATIC S7 process control system opens up entirely new dimensions. Contrary to conventional process control systems, it offers a uniquely scalable architecture with powerful engineering tools and comprehensive auxiliary capabilities. The modular architecture of SIMATIC S7 allows it to adapt flexibly to different customer requirements and plant sizes and to grow easily along with subsequent increases of capacity or technological changes. Hence the SIMATIC S7 can be the best choice. Different sensors, hardware and software solutions are used for optimization of different processes, so no unique solution is possible. However, the similarities in process can definitely help the user to derive at the desired solution very quickly.

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